SEARCH FOR X-RAY BURSTS IN THE INTEGRAL/IBIS DATA OF 2003-2005 AND DISCOVERY OF THE NEW X-RAY BURSTER IGR J17364-2711/17380-3749

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ABSTRACT

All the observations performed with the IBIS telescope aboard the INTEGRAL observatory during the first 2.5 years of its in-orbit operation have been analyzed to find X-ray bursts. There were 1788 statistically confident events with a duration from 5 to 500 s revealed in time records of the 15–25 keV count rate of the IBIS/ISGRI detector, 319 of them were localized and, with one exception, identified with persistent X-ray sources. The known bursters were responsible for 215 of the localized events. One burst was detected from AXJ1754.2-2754, the source previously unknown as a burster, and another burst — from a new source. There was duality in determining its position — its name could be either IGR J17364-2711 or IGR J17380-3749. Curiously enough, the 138 bursts were detected from one X-ray burster — GX 354-0.

Key words: neutron stars; X-ray bursts; bursters.

1. INTRODUCTION

Many X-ray bursts detected by orbital observatories are associated with thermonuclear explosions on weakly magnetized accreting neutron stars (type-I bursts). They provide us with direct information on processes near the surface of neutron stars under conditions of strong gravity, extreme pressure and high temperatures. The detection of type-I bursts, along with the detection of coherent pulsations, serves the most important criterion for identifying the nature of the compact object in X-ray binaries.

Type-I bursts are generally observed from weak X-ray sources (or transients in their quiescent state). During the burst the luminosity of such a source (a burster) can increase by two or three orders of magnitude relative to its persistent level, reaching a critical Eddington value. The typical burst at the Galactic center distance (~ 8.5 kpc) provides a peak flux of about 2–3 Crab and can be easily detected. This opens up a possibility for using the bursts in searching for previously unknown bursters with persistent X-ray fluxes below the level of reliable detection by currently available wide-field instruments.

The INTEGRAL observatory [5] is best suited for performing such a search. It is equipped with unique wide-field telescopes that allow sky fields with an area of $\sim$ 1000 square degrees to be simultaneously studied with a flux sensitivity up to 1 mCrab (over several hours of observations) and an angular resolution reaching several arcminutes. In addition, INTEGRAL devotes up to 85% of the whole time to observations of the Galactic center region and the Galactic plane, where the bulk of the Galactic stellar mass is concentrated.

In this paper, to find X-ray bursts, we analyze time records of the total 15-25 keV count rate of the IBIS/ISGRI detector [3, 4] aboard INTEGRAL obtained from February 10, 2003, through August 31, 2005. The main objective of this study was an attempt to discover new bursters or fast X-ray transients. Some of the presented results (corresponding to the observations before July 2, 2004) have already been published in [1].

2. OBSERVATIONS AND DATA ANALYSIS

Our analysis of the IBIS data was based on the OSA 4.2 software package. Using the list of events from its GTI task, we reproduced time records of the count rate (see Fig. 1) for each individual INTEGRAL observation (cor-

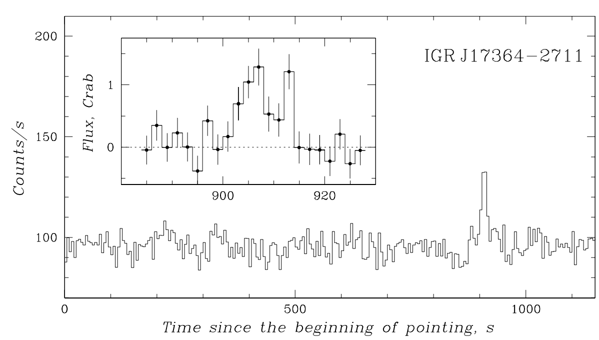

Figure 1. IBIS/ISGRI count rate in the 15-25 keV band recorded on February 17, 2004, during the pointing when an X-ray burst from a previously unknown burster was discovered (the insertion shows its reconstructed profile).

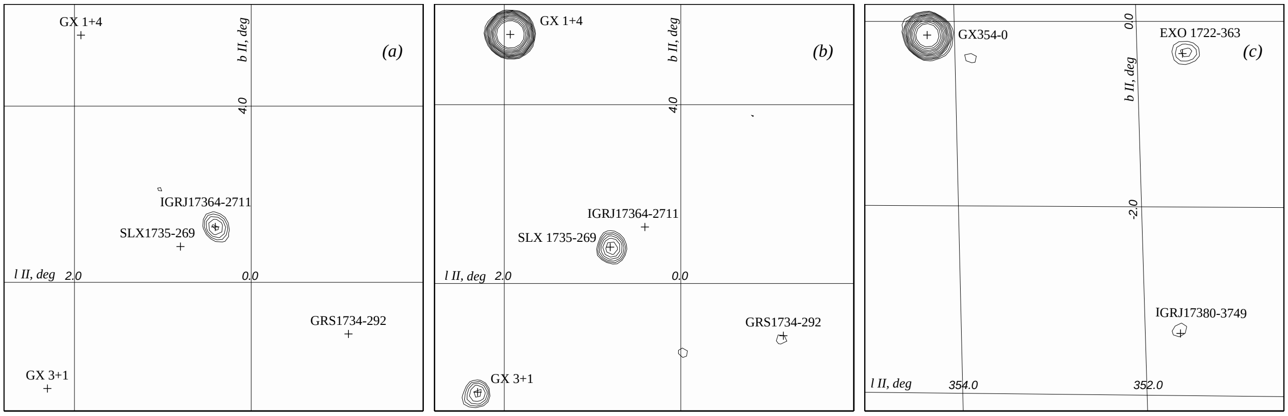

Figure 2. X-ray images obtained with IBIS/ISGRI on February 16–17, 2004: (a) during 15 s of the burst detected from the new burster IGR J17364-2711 (15-25 keV), (b) and (c) during the entire observing session except the burst interval (165 ks, 18–45 keV). Contours show regions of confident detection of sources at the S/N levels of $3.5, 4.4, 5.5, 6.8, 8.5, ..., 40$.

responding to an individual pointing) with a time resolution of 5 s. More than 32800 individual observations were analyzed for the presence of bursts with a total exposure time of over 67 Ms. An excess of the signal-to-noise ratio $(S-\overline{S})/N$ above the preset threshold $s_0 = 5.25$ in a particular time bin served a criterion for a burst. Since the number of counts in each bin obeys a Poisson distribution, there is a low, but finite probability $p_0 \simeq 8\times10^{-8}$ (for $s_0 \simeq 5.25$) of recording a random spike even in the absence of a real burst. The selected threshold s_0 ensures that only one such spike in the entire time series (with $M \sim 1.3\times10^{7}$ bins) may be recorded ($p_0 \times M \simeq 1$). Since the total count rate of the detector depended on the emission from all sources within the IBIS field of view (FOV), the mean count rate $\overline{S}$ and the noise level $N = (\overline{S^2} - \overline{S}^2)^{1/2}$ were determined independently for each pointing. For all the detected bursts, we reconstructed the images of the sky area within the IBIS FOV (the IMA phase of OSA 4.2) accumulated with the same exposure at the burst time and immediately before the burst and compared the statistical significance of sources detected in them to reveal the burst source.

3. RESULTS

There were 1788 bursts found in the IBIS/ISGRI count rate histograms; the sources of 319 bursts were also detected in the IBIS images. Some of them were associated with cosmic GRBs (11 events), activity of SGR 1806-20 (59) or several bright XBs (32). The other 217 of the localized bursts (see Table) were associated with 15 known and 2 new X-ray bursters (138 of them — with GX 354-0). Among the new bursters one was actually a weak unidentified source AX J1754.2-2754 discovered by ASCA in 1999 (note that 1A 1246-588, one of the 15 known sources, was identified as a burster only a few weeks before this Workshop — due to an intense type-I burst detected from its positon by RXTE [2]). An X-ray burst from the second new burster was detected on February 17, 2004, when IBIS observed the Galactic center region. Because of peculiarity of the IBIS coded mask, the burster position was determined with duality [1]: it could be either R.A.=$17^{\rm h}36^{\rm m}28^{\rm s}$, Decl.=$-27°11'56''$ (see Fig. 2a) or R.A.=$17^{\rm h}38^{\rm m}05^{\rm s}$, Decl.=$-37°49'05''$ (epoch 2000.0, error radius for the positions is $2'$). The S/N ratio was the same ($\simeq 8.9$) for both the positions, however in the first case this ratio was reached with the larger number of counts (394) compared to the second case (316). Taking this fact into account we named the source IGR J17364-2711, although the second name, IGR J17380-3749, cannot be completely rejected. As Fig. 2b shows IGR J17364-2711 was not seen in the image accumulated during the entire observing session of February 16–17, except the pointing during which the burst occurred. Fig. 2c shows another part of the same image with an excess near the position of IGR J17380-3749. It is however too weak ($S/N \simeq 4.3$) to ensure the presence of a real persistent source.

The photon flux measured during $\Delta T \simeq 1$ s at the burst maximum reached 1.6 ± 0.3 Crab, that corresponded to a 15–25 keV luminosity $\simeq 8\times10^{37}$ erg s^{-1} at the Galactic center distance of 8.5 kpc. The burst spectrum was very soft and the flux at energies $\gtrsim 30$ keV fell below the detection level. Assuming the spectrum to have a Wien shape with $kT \simeq 2.5-2.8$ keV typical of bursts with photospheric expansion, we found the bolometric luminosity of this burst, $L_{\rm B} \simeq (4-5)\times10^{38}$ erg s^{-1} which is actually very close to the Eddington one. It was not possible to refine kT from observations in the standard X-ray band (with the INTEGRAL/JEM-X monitor) since the burst occurred at the very edge of the JEM-X FOV, narrower than the IBIS one, and was not detected.

The 3σ limit on the persistent 18–45 keV flux from IGR J17364-2711 was 3 mCrab. Assuming a power-law spectrum with the photon index $\gamma \simeq 2.1$ for the source, we obtain a fairly stringent limit on its 2–45 keV luminosity, $L_{\rm X} \lesssim 1.5\times10^{36}$ erg s^{-1}. Thus, IGR J17364-2711 may complement the list of X-ray bursters that have never been observed in a state of persistent X-ray emission.

ACKNOWLEDGMENTS

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REFERENCES

[1] Chelovekov I., Grebenev S., et al., 2006, AstL 32, 456
[2] Kuulkers E., Levine A.M., 2006, ATel 837
[3] Lebrun F., et al., 2003, A&A 411, L141
[4] Ubertini P., et al., 2003, A&A 411, L131
[5] Winkler C., et al., 2003, A&A 411, L1

Table. X-ray bursts detected by the IBIS/ISGRI telescope in the 15-25 keV band and their peak fluxes (in Crab units)

#	Source	Burst maximum ($\Delta T \simeq 1$ s) UTC	h:m:s	Crab	#	Source	Burst maximum ($\Delta T \simeq 1$ s) UTC	h:m:s	Crab
1	GX 354-0	28.02.03	07:55:06	2.52	50	GX 354-0	13.09.03	16:40:43	1.03
2	GX 354-0	01.03.03	00:04:50	2.48	51	GX 354-0	13.09.03	22:28:39	2.97
3	GX 354-0	01.03.03	16:05:33	3.04	52	GX 354-0	14.09.03	15:02:23	2.72
4	GX 354-0	02.03.03	07:42:22	3.04	53	GX 354-0	14.09.03	20:55:10	2.17
5	4U 1636-536	04.03.03	19:18:02	1.13	54	GX 354-0	15.09.03	09:40:18	1.71
6	4U 1702-429	09.03.03	21:51:13	2.93	55	GX 354-0	15.09.03	15:49:09	3.10
7	4U 1608-522	09.03.03	22:35:05	2.57	56	SLX 1735-269	15.09.03	17:42:29	2.16
8	GX 354-0	12.03.03	10:22:26	2.70	57	GX 354-0	17.09.03	02:42:50	2.79
9	4U 1702-429	12.03.03	11:11:03	3.09	58	GX 354-0	17.09.03	08:58:31	2.95
10	4U 1608-522	13.03.03	13:49:37	2.61	59	GX 354-0	18.09.03	10:33:36	2.42
11	4U 1702-429	15.03.03	02:38:07	2.44	60	GX 354-0	19.09.03	16:12:10	3.18
12	4U 1702-429	15.03.03	18:22:49	1.74	61	GX 354-0	20.09.03	05:40:37	3.70
13	GX 354-0	15.03.03	20:36:46	1.22	62	GX 354-0	20.09.03	23:47:03	3.44
14	GX 354-0	03.04.03	08:40:18	3.10	63	GX 354-0	21.09.03	14:07:40	2.93
15	Aql X-1	06.04.03	07:42:15	1.42	64	GX 354-0	22.09.03	17:38:26	2.81
16	4U 1724-307	06.04.03	18:32:31	1.26	65	GX 354-0	23.09.03	02:16:11	2.40
17	GX 354-0	06.04.03	19:45:29	1.54	66	SLX 1735-269	23.09.03	05:11:43	1.04
18	GX 354-0	07.04.03	03:26:31	1.78	67	GX 354-0	23.09.03	10:53:38	2.37
19	4U 1636-536	11.04.03	18:13:18	0.52	68	GX 354-0	23.09.03	18:15:09	2.61
20	4U 1702-429	15.04.03	06:47:16	2.54	69	SLX 1735-269	23.09.03	23:13:11	1.05
21	4U 1812-12	21.04.03	03:36:36	2.55	70	GX 354-0	24.09.03	03:52:12	3.18
22	4U 1812-12	25.04.03	10:54:25	3.60	71	GX 354-0	24.09.03	11:01:26	3.00
23	2S 0918-549	16.06.03	20:09:13	3.61	72	SAX J1712.6-3739	24.09.03	14:00:09	2.18
24	4U 1702-429	18.08.03	10:05:10	2.46	73	GX 354-0	24.09.03	18:20:21	2.63
25	GX 354-0	23.08.03	16:14:02	0.89	74	4U 1608-522	26.09.03	02:38:55	3.73
26	GX 354-0	24.08.03	22:20:44	1.69	75	4U 1608-522	26.09.03	15:34:51	3.79
27	SAX J1712.6-3739	25.08.03	18:45:43	1.78	76	4U 1608-522	27.09.03	05:10:24	4.95
28	GX 354-0	27.08.03	19:59:14	1.82	77	4U 1812-12	27.09.03	16:08:45	3.06
29	GX 354-0	28.08.03	01:24:04	0.91	78	GX 354-0	04.10.03	22:06:42	1.68
30	GX 354-0	28.08.03	06:01:30	1.86	79	GX 354-0	05.10.03	09:34:42	2.72
31	GX 354-0	29.08.03	14:31:29	2.01	80	GX 354-0	08.10.03	09:58:37	1.03
32	GX 354-0	29.08.03	19:23:36	2.19	81	GX 354-0	17.02.04	04:47:50	3.27
33	GX 354-0	31.08.03	15:54:18	1.13	82	IGR J17364-2711	17.02.04	14:41:30	1.59
34	GX 354-0	03.09.03	03:26:34	1.62	83	GX 354-0	19.02.04	21:06:44	2.13
35	GX 354-0	03.09.03	08:39:32	1.49	84	GX 354-0	20.02.04	02:44:00	2.11
36	GX 354-0	03.09.03	18:02:39	1.08	85	GX 354-0	20.02.04	12:00:23	1.13
37	4U 1812-12	06.09.03	00:23:32	4.04	86	GX 354-0	27.02.04	10:55:16	3.08
38	GX 354-0	07.09.03	20:30:07	1.55	87	GX 354-0	27.02.04	13:32:36	1.53
39	GX 354-0	08.09.03	13:41:36	2.66	88	GX 354-0	27.02.04	15:32:03	2.11
40	4U 1724-307	08.09.03	18:48:30	1.48	89	GX 354-0	02.03.04	07:34:38	1.52
41	GX 354-0	08.09.03	19:41:21	2.63	90	GX 3+1	02.03.04	09:25:34	0.98
42	GX 354-0	09.09.03	03:11:36	2.95	91	4U 1724-307	03.03.04	04:14:60	1.40
43	GX 354-0	09.09.03	16:28:54	1.45	92	GX 354-0	08.03.04	04:14:45	1.03
44	GX 354-0	09.09.03	22:22:24	2.58	93	4U 1608-522	20.03.04	20:59:32	3.72
45	GX 354-0	11.09.03	05:04:28	3.92	94	4U 1608-522	21.03.04	01:03:47	1.83
46	GX 354-0	11.09.03	10:57:50	1.99	95	Aql X-1	24.03.04	17:03:35	1.58
47	GX 354-0	11.09.03	21:59:51	2.92	96	GX 354-0	29.03.04	02:40:47	0.99
48	GX 354-0	12.09.03	03:12:25	2.04	97	GX 354-0	30.03.04	03:25:33	1.25
49	GX 354-0	12.09.03	09:22:40	2.58	98	SLX 1744-299	30.03.04	03:37:46	0.81

#	Source	Burst maximum ($\Delta T \simeq 1$ s) UTC	h:m:s	Crab	#	Source	Burst maximum ($\Delta T \simeq 1$ s) UTC	h:m:s	Crab
99	KS 1741-293	30.03.04	03:43:45	0.88	159	4U 1702-429	25.02.05	13:58:35	1.80
100	GX 354-0	31.03.04	03:09:05	0.85	160	4U 1702-429	27.02.05	16:08:41	2.47
101	GX 354-0	01.04.04	23:36:53	0.99	161	4U 1608-522	03.03.05	19:46:16	3.80
102	Aql X-1	28.04.04	07:54:48	1.96	162	4U 1608-522	04.03.05	13:13:59	2.09
103	Aql X-1	01.05.04	22:56:47	1.89	163	4U 1608-522	05.03.05	22:37:27	2.56
104	GX 354-0	22.08.04	14:37:53	1.75	164	4U 1636-536	06.03.05	01:25:52	1.37
105	SLX 1735-269	23.08.04	17:23:59	1.04	165	4U 1608-522	06.03.05	12:30:56	4.21
106	GX 354-0	23.08.04	21:53:59	1.59	166	4U 1608-522	06.03.05	22:55:52	5.02
107	GX 354-0	01.09.04	01:22:21	0.77	167	4U 1608-522	08.03.05	07:56:40	5.07
108	GX 354-0	01.09.04	15:25:02	1.65	168	4U 1608-522	09.03.05	14:08:27	4.27
109	GX 354-0	01.09.04	19:26:43	1.61	169	GX 354-0	17.03.05	08:16:32	1.11
110	GX 354-0	01.09.04	23:12:18	1.44	170	GX 354-0	18.03.05	00:53:47	2.52
111	GX 354-0	02.09.04	03:23:25	2.80	171	GX 354-0	18.03.05	23:12:29	2.80
112	GX 354-0	02.09.04	07:16:21	1.65	172	GX 354-0	20.03.05	19:38:07	2.50
113	GX 354-0	03.09.04	14:32:30	2.97	173	GX 354-0	20.03.05	23:28:19	2.33
114	GX 354-0	03.09.04	18:39:35	1.83	174	GX 354-0	21.03.05	03:40:50	2.45
115	GX 354-0	03.09.04	23:17:42	1.66	175	SAX J1712.6-3739	21.03.05	19:06:05	2.57
116	GX 354-0	04.09.04	09:06:02	3.40	176	GX 354-0	22.03.05	01:24:37	2.33
117	GX 354-0	04.09.04	16:19:11	0.84	177	GX 354-0	22.03.05	23:59:45	2.62
118	GX 354-0	04.09.04	23:50:03	3.55	178	GX 354-0	23.03.05	11:44:33	1.68
119	4U 1702-429	07.09.04	10:51:47	2.26	179	GX 354-0	24.03.05	15:39:10	1.75
120	GX 354-0	07.09.04	11:09:51	1.69	180	GX 354-0	24.03.05	21:14:22	2.43
121	GX 354-0	07.09.04	14:27:14	3.01	181	GX 354-0	25.03.05	02:22:48	2.53
122	GX 354-0	07.09.04	18:04:56	1.03	182	GX 354-0	25.03.05	23:51:29	2.45
123	GX 354-0	07.09.04	21:30:48	1.29	183	GX 354-0	26.03.05	09:05:20	3.08
124	GX 354-0	08.09.04	01:54:26	2.61	184	GX 354-0	27.03.05	08:45:39	2.00
125	GX 354-0	08.09.04	09:00:22	1.94	185	4U 1702-429	27.03.05	11:49:04	1.98
126	GX 354-0	08.09.04	12:41:39	1.79	186	GX 354-0	27.03.05	15:23:04	2.21
127	GX 354-0	08.09.04	15:50:10	3.27	187	GX 354-0	28.03.05	01:47:04	0.73
128	4U 1702-429	08.09.04	17:43:26	1.05	188	H 0614+091	31.03.05	07:13:08	8.43
129	4U 1636-536	11.09.04	04:16:54	1.36	189	GX 354-0	04.04.05	01:17:29	1.39
130	GX 354-0	15.09.04	12:56:11	1.45	190	4U 1702-429	04.04.05	04:55:51	2.92
131	GX 354-0	19.09.04	12:00:32	1.39	191	4U 1702-429	06.04.05	08:56:54	1.81
132	GX 354-0	22.09.04	17:37:15	1.44	192	GX 354-0	07.04.05	10:06:45	0.90
133	GX 354-0	23.09.04	04:10:50	1.56	193	4U 1702-429	08.04.05	06:04:19	2.04
134	GX 354-0	23.09.04	07:37:29	0.97	194	4U 1702-429	10.04.05	03:01:03	2.45
135	GX 354-0	30.09.04	11:47:22	1.74	195	GX 354-0	10.04.05	07:42:23	1.04
136	GX 354-0	30.09.04	14:54:25	2.50	196	GX 354-0	14.04.05	06:33:29	1.33
137	GX 354-0	01.10.04	03:11:27	0.45	197	AX J1754.2-2754	16.04.05	22:11:04	1.36
138	GX 354-0	01.10.04	06:53:21	2.27	198	4U 1724-307	16.04.05	22:17:44	1.15
139	GX 354-0	01.10.04	14:28:34	2.60	199	4U 1812-12	28.04.05	06:00:38	4.65
140	GX 354-0	01.10.04	22:11:34	2.60	200	1A 1246-588	27.06.05	11:06:54	2.99
141	GX 354-0	02.10.04	01:58:58	2.45	201	GX 354-0	12.08.05	16:47:26	1.11
142	GX 354-0	02.10.04	05:59:15	2.46	202	4U 1608-522	12.08.05	22:09:58	3.99
143	GX 354-0	02.10.04	10:12:10	1.71	203	GX 354-0	17.08.05	03:06:31	2.16
144	GX 354-0	02.10.04	14:16:06	3.06	204	4U 1608-522	17.08.05	08:55:27	3.67
145	GX 354-0	02.10.04	21:50:09	3.05	205	GX 354-0	25.08.05	16:19:41	2.50
146	4U 1812-12	04.10.04	03:15:49	4.29	206	4U 1636-536	25.08.05	21:28:22	0.89
147	GX 354-0	16.10.04	07:27:17	1.20	207	4U 1702-429	26.08.05	07:07:35	2.59
148	GX 354-0	17.10.04	10:58:54	1.25	208	4U 1608-522	26.08.05	10:51:25	5.11
149	GX 354-0	20.10.04	06:37:13	1.05	209	4U 1608-522	27.08.05	11:34:03	4.60
150	GX 354-0	20.10.04	11:35:45	1.35	210	GX 354-0	28.08.05	13:24:16	2.90
151	4U 1702-429	18.02.05	15:35:56	1.92	211	GX 354-0	28.08.05	21:39:42	2.27
152	4U 1702-429	19.02.05	02:26:13	2.03	212	GX 354-0	29.08.05	08:29:35	2.10
153	4U 1702-429	19.02.05	14:27:24	2.84	213	4U 1608-522	29.08.05	10:39:19	4.52
154	4U 1636-536	19.02.05	15:38:52	1.34	214	4U 1636-536	29.08.05	13:47:36	0.82
155	GX 354-0	21.02.05	10:06:19	1.17	215	4U 1702-429	30.08.05	06:21:50	3.00
156	4U 1636-536	22.02.05	13:48:56	1.14	216	GX 354-0	30.08.05	12:10:38	4.62
157	4U 1702-429	24.02.05	20:22:07	1.13	217	4U 1702-429	30.08.05	16:45:34	1.32
158	4U 1702-429	25.02.05	04:53:55	2.27					